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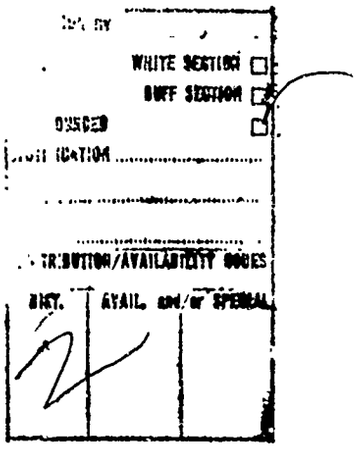

HUMAN FACTOR PROBLEMS IN ANTI-SUBMARINE WARFARE

Research under this contract was directed toward analytical and experimental studies of the factors affecting the detection, classification and maintenance performance of sonar technicians in surface ship, submarine and airborne ASW systems. The contract began on July 15, 1958 and was concluded on May 17, 1967. During this period a total of 36 technical reports were issued on such diverse topics as operator vigilance, operating technique in the detection and classification of targets, clue recognition, sonar maintenance, training, and the design of sonar equipment and ASW systems for maximum effectiveness. The work was performed under the cognizance of the Personnel and Training Branch, Psychological Sciences Division, ONR, with additional financial support from Undersea Programs, ONR; the Naval Ship Systems Command, the Bureau of Naval Personnel and the former Bureau of Ordnance.

Human Vigilance and Target Detection

ASW operations emphasize some of the classic problems concerned with human vigilance. Although the operator's task is often boring and monotonous, success of the mission often depends on his maintaining attention for low probability events over prolonged periods of time. Target signals are a rare occurrence, the visual search task is demanding, and performance feedback is almost totally lacking during routine operations.

Early work under this contract involved a review of experimental studies on human attention and vigilance as might be pertinent to the sonar watchstander's task and the definition of additional research needed to properly define the important variables in this area of behavior. A number of key studies were conducted by Buckner, Harabedian and McGrath directed toward such questions as the magnitude of individual differences in vigilance performance, the effect of signal rate and the intersignal interval on detection probability, and the effects of monitoring signals simultaneously through two sensory channels (audio and video) on detection performance. The technical reports produced on the topic of vigilance were as follows:

206-1 Review and critique of the literature on vigilance performance. McGrath, Harabedian & Buckner, 1959. Unclassified.

206-2 A study of individual differences in vigilance performance. Buckner, Harabedian & McGrath, 1960. Unclassified.

206-3 The probability of signal detection in a vigilance task as a function of intersignal interval. Harabedian, McGrath & Buckner, 1960. Unclassified.

206-4 An exploratory study of the correlates of vigilance performance. McGrath, Harabedian & Buckner, 1960. Unclassified.

206-6 The effects of irrelevant environmental stimulation on vigilance performance. McGrath, 1960. Unclassified.

206-7 Irrelevant stimulation and vigilance under fast and slow stimulus rates. McGrath & Hatcher, 1961. Unclassified.

206-8 A comparison of performance on single and dual sensory mode vigilance tasks. Buckner & McGrath, 1961. Unclassified.

206-9 Signal detection as a function of intersignal interval duration. McGrath & Harabedian, 1961. Unclassified.

206-13 The accuracy of judgments of eye fixations: A methodological note on vigilance. McGrath & Hatcher, 1961. Unclassified.

206-14 Human performance during five days confinement. McGrath, Maag, Hatcher & Breyer, 1962. Unclassified.

Many of the findings from the HFR research on vigilance were not only of practical importance but stimulated theoretical developments as well. As a result of this research HFR was host to an international symposium on vigilance in 1961. Under a separate contract, Buckner and McGrath later published the symposium proceedings (Vigilance: A Symposium, McGraw-Hill, 1963) which has served as a point of departure for renewed interest in the study of human attention.

Target Detection and Operating Technique

In addition to the fundamental issue of the operator's attention or alertness, there are several other critical factors that affect the probability of detection. Some of these are objective such as the calibration and alignment of the sonar, the adjustment of bias and gain in the receiver, etc. Others are subjective. The most important factor in the latter category appears to be the operator's personal criterion of what constitutes an echo worthy of investigation.

In an attempt to study the role of the operator's personal criterion in target detection, HFR developed a motion picture target detection test using target signals recorded at sea through active scanning sonar systems. The employment of this test experimentally produced the first objective evidence of operator differences in what was interpreted to be a target echo. The perceptual process involved, sometimes called echo recognition, constitutes a kind of preliminary or first-stage target classification which precedes the decision to make a more detailed investigation of the target. Targets which do not pass this initial screening are not fully classified, and usually not even reported. Consequently the importance of the process to target detection in ASW systems is considerable.

In a series of studies, Baker, Harabedian and Parker investigated the effects of what might be called operating technique on the probability of target detection. These studies included a definitive investigation of how the requirement to visually search a PPI scope affects detection probability. For the first time the often-noted difference in target detection between alerted and non-alerted search was systematically studied and quantified. In addition, both laboratory and shipboard studies were conducted of the influence of the operator's use of bias and gain controls on detection probability.

The technical reports relating to operating technique and target detection were as follows:

206-5 The development of an experimental motion picture sonar target recognition test. McGrath, High & Mackie, 1960. CONFIDENTIAL.

206-16 A study of target detection by sonar operators. Baker & Harabedian, 1962. Unclassified.

206-20 Improvement in sonar operator detection performance consequent to the use of optimum bias and gain. Baker, 1963. Unclassified.

206-26 Sonar operator detection performance at sea. Baker, Parker & Rittger, 1964. Unclassified.

The results of these studies clearly indicated the dependence of target detection probability on operator variables and operating techniques. It was shown that many db's of detection capability stand to be gained (or lost) as a result of these operator related factors. Fortunately, there is some evidence of increasing awareness in ASW commands of the importance of these factors.

Target Classification Technique

In 1959 HFR conducted a "workshop" at the ASW Tactical School, Norfolk, on the topic of active sonar target classification methodology. All major ASW operational and training commands were represented. The objective was to establish meaningful communication among the research community, training personnel, and operating ASW forces concerning both research results and operational experience in target classification. As a result of this workshop recommendations were made which have had a continuing impact on the development of sonar operating procedures and ASW systems design. Suggestions were made for the improvement of displays and controls for target classification, the use of human engineers early in the design of sonar systems, the systematic collection of recorded submarine and non-submarine contact data, the upgrading of the role of the ASW officer, and the adoption of new procedures in target classification technique. While not all of the recommendations have been completely implemented, there is evidence of some progress in each area of recommendation.

An immediate consequence of the exchange of information at the workshop was the publication by Mackie, Parker and Gavin of the first report on a systematic and logical method of target classification using active scanning sonars. This publication reflected the many changes that had occurred in sonar transmission, signal processing, and display techniques since the end of World War II. It subsequently was published by the Navy as NavPers 92728 and has remained the principal treatment of the subject for the past eight years. It has been used as a text by both the U.S. and Canadian Navies and has served as a model for a similar publication in the British Navy.

A number of other HFR reports have been directed toward the conceptual problems in sonar target classification and the analysis of target clues displayed by operating sonar systems. During the contract detailed analyses were conducted of the clues presented by SQS-29, SQS-23, and AQS-10 sonars. In each case the procedure was to collect magnetic tape and motion picture recordings of the information displayed by the sonars during contact with representative submarine and non-submarine targets. These were then analyzed in the HFR laboratory for reliable and discriminating clues and clue patterns. The recorded materials subsequently were used as stimuli for experimental training studies and, eventually, for the development of training aids. They are presently in use at the Key West and San Diego schools for training both operators and officers in target classification.

The availability of these materials has enabled a number of important questions to be investigated experimentally. For

instance, it has been possible to conduct studies of the utility of such innovations in display techniques as speed translation, experimental A-scans, and doppler discriminators. By measuring the human responses to target signals under normal and experimental display conditions, definitive answers concerning the worth of several proposed display techniques have been obtained. This has sometimes resulted in recommendations not to pursue a proposed display technique where it was indicated that that technique would have added considerably to the cost of a system but marginally, or not at all, to its performance effectiveness.

Studies conducted under this contract on target classification and clue recognition included the following:

206-0 Target classification using active scanning sonar. Mackie, Gavin & Parker, 1959. CONFIDENTIAL.

206-10 Further experimentation in training target classification principles applicable to active scanning sonars. Gavin, Mackie & Harris, 1961. CONFIDENTIAL.

206-11 The production of target classification information by submarines. Mackie, 1961. CONFIDENTIAL.

206-12 Three studies of sonar doppler discrimination. Harabedian & Parker, 1961. CONFIDENTIAL.

206-15 Feasibility study and suggested program for collecting recorded AQS-10 detection and classification materials. Gavin, 1962. CONFIDENTIAL.

206-17 Notes on the problem of training operators for the AQS-10 sonar. Baker, 1962. CONFIDENTIAL.

206-22 Further study of PPI pip shapes in relation to sonar target classification. Rittger, Tabachnick & Mackie, 1963. CONFIDENTIAL.

206-23 Studies of doppler recognition using the SQS-23 sonar. Harabedian & Mackie, 1963. CONFIDENTIAL.

206-29 Observations on the evaluation of the TRESI target classification system. Gavin & Mackie, 1965. CONFIDENTIAL.

206-31 Doppler discrimination in relation to echo duration and display frequency. Harabedian & Gavin, 1965. CONFIDENTIAL.

206-32 A preliminary analysis of target classification information obtained from the AN/AQS-10 airborne sonar system. Gavin & Seltzer, 1965. CONFIDENTIAL.

206-35 Sonar target classification using optical interferometry: An exploratory study. Davidson, Dossett & Hall, 1965. CONFIDENTIAL.

Research performed under this contract also was instrumental in HFR's participation in the development of two target classification aids: the HHIP and the MITEC. The HHIP, designed and constructed for NEL by Gavin and Seltzer, is the only classification aid ever adopted for general fleet use. The MITEC, designed by HFR and built by Waddell Dynamics, while not recommended for service use, nevertheless reflects the most sophisticated attempt to date to provide operators with a much needed aid to the logic of sonar target classification. Interest in these comparatively simple devices has increased periodically as much more expensive systems, utilizing general purpose computers, have proved disappointing for meeting fleet needs in target classification.

One of the most important implications for new developments in target classification, directly traceable to research under this contract, is a technique developed by Dossett and Hall for analyzing target echoes by means of optical interference patterns. This processing and display procedure reveals evidence of detailed echo structure never before seen in a visual sonar display. The experimental evidence collected thus far strongly suggests that this technique may make it possible to classify targets with a higher degree of accuracy, while using fewer successive echoes, than with any previous classification method.

Sonar Maintenance and Training

Experience at sea during a number of data collection cruises indicated to the HFR staff that the calibrative status of sonar equipments in the fleet is often far from optimum. However, the prevalence of sub-standard sonar performance in detection capability, quality of classification information, and accuracy of fire control information, was largely unknown. Consequently, several studies were directed toward objective measurement of the status of sonar equipment and the level of technical knowledge of the sonarmen responsible for maintenance. It was to this class of problems that our investigations have been directed.

Two such studies were directed toward the SQS-23 sonar and the ASPECT target classification equipment. It was clear from these studies that the principal problem in sonar maintenance is not the occasional case of complete equipment breakdown, which is highly visible to all, but rather in detecting the much more frequent and subtle case when the equipment is limping, i.e., operating in a condition substantially below its peak capability.

In this research emphasis also has been placed upon training for sonar maintenance and design of equipment for maintainability. Because of the evident differences in philosophy, the differences between the training of U.S. Navy sonar technicians and that received by technicians in other NATO navies was given special attention.

The reports produced in this area of investigation included:

206-24 The effect of calibration accuracy on basic sonar operations. Parker, 1964. CONFIDENTIAL.

206-27 Sonar operation, maintenance and research: Some contrasts between the U.S. and Western European navies. Mackie, 1964. CONFIDENTIAL.

206-33 Maintenance status and fleet acceptance of ASPECT target classification equipment. Simpson & Parker, 1965. CONFIDENTIAL.

206-34 Sonar equipment design and maintenance training in selected European navies. Mackie & Parker, 1965. CONFIDENTIAL.

The influence that these studies have had on Navy training practices for sonar maintenance technicians is a matter for conjecture. It is notable, however, that the training of sonar technicians has been extended appreciably within the last year. Further, there has been increasing emphasis on the technical training of the ASW officer. In addition, there is some direct evidence of the adoption, by the instructors at the Fleet Sonar School, of HFR procedures for internal bearing alignment and range calibration of the SQS-23. An HFR-developed checklist for determining the calibrative status of the SQS-23 and ASPECT equipment also was adopted for use by the Electronics Maintenance Engineering Center, Norfolk.

Perhaps the most important long-term consequence of these studies is reflected in Parker's design and development of a Generalized Sonar Maintenance Trainer for the U.S. Naval

Training Device Center. During work under this contract, Parker was impressed by the equipment specificity of traditional maintenance training and the rote procedures employed in conducting sonar maintenance. He has now developed a generalized training device that should enable maintenance training to occur at a more meaningful conceptual level, at a fraction of the cost of traditional maintenance training, and permitting far greater opportunity for individual trainees to practice critical calibrations and alignments.

Sonar Displays and Systems Design

During the course of this contract HFR personnel have had increasing opportunities to contribute to design thinking on sonar systems in the developmental stage. Staff members have been invited to make suggestions on the design of training and operational equipment for airborne, surface and submarine ASW systems. Our recommendations also have been solicited by a number of Navy agencies on specific proposals for signal processing and display techniques. Parker has served as a technical consultant on such diverse topics as an integrated classification console (for NEL); characteristics desirable in graphic recorders, automatic gain control circuitry, and SQQ-23 sonar displays (for NSSC); and on the construction and administration of performance tests to sonar maintenance personnel (for EMEC).

Project personnel also submitted to NSSC a set of considerations concerning the advantages and limitations of ASPECT that reflected the results of their comparative recordings of target echoes using a conventional TRR and the PGR (forerunner of ASPECT). In response to inquiries from COMOPTEVFOR, HFR provided suggestions on appropriate procedures for the operational testing of the ASCAC system. In response to an inquiry from COMTRALANT, project personnel defined key issues involved in the proposed use of speed translation for discriminating clues in active sonar echoes. In this latter instance, and others, HFR has been able to indicate to the Navy that newly proposed processing or display techniques would not have a beneficial effect on operator performance. Despite their negative character, the value of such recommendations in terms of dollar. saved on ineffective innovations, is believed to have been considerable.

A number of other equipment-related developments are directly traceable to the knowledge and skills developed by project personnel under this contract. For example, Gavin has demonstrated the value of a range recorder for target

classification in the AQS-10/13 sonar system. He has also developed a doppler discriminator based on a unique application of the Wein bridge. The success of this discriminator has been limited, however, by instability in other SQS-23 circuitry. Gavin also played a key role in the Navy's technical evaluation of the TRESI target classification system.

Research performed under this contract has also been beneficial to work pursued under a number of other related contracts for ONR. One of these was concerned with defining the operator tasks and critical performance factors that would be involved in an air/sea ASW craft. Another involved the application of findings from research performed under this contract to the conceptual development of an ASW countermeasure system.

Technical reports generally concerned with sonar equipment and systems operation included:

206-18 Notes on some human factor problems in fixed wing ASW. Baker, 1962. CONFIDENTIAL.

206-21 The display of probabilistic solutions in sonar target classification. Mackie, 1963. CONFIDENTIAL.

206-19 Degree of simulation desirable in ASW trainers. Mackie, 1965. CONFIDENTIAL.

206-30 Design recommendations for the AN/BQS-6 active sonar console. Parker & Mackie, 1965. CONFIDENTIAL.

206-36 A review of some human factor considerations in the BQR-7 DIMUS (digital pre-formed beam) development. Harper, 1966. CONFIDENTIAL.

Development of Training Materials and Operator Performance Tests

Reference has been made previously to the collection of recorded target data made for a variety of sonar systems. Subsequent to analyzing these materials for the validity of their classification clues, HFR has typically taken two additional steps: (1) development of operator performance tests for target classification (and detection); and (2) transformation of the recorded materials into edited sequences suitable for demonstration and training.

Under this contract, test and training materials were developed for three sonar systems: SQS-23, AQS-10/13 and BQQ-2*. The availability of these recorded materials has not only been extremely valuable for operator training but has provided a means for obtaining the only objective measures of their target classification skill. The most recent work under this contract has been directed, for example, toward an investigation of how submarine sonar operators combine the use of audio and video displays (BQQ-3) to classify targets. A number of critical questions concerning level of performance, operating procedure, and classification logic remain to be answered. These will be the subject of investigation under a subsequent contract.

The recorded target signals collected by HFR have also been influencial in a variety of other Navy-sponsored ASW projects. While it is difficult to assess the impact of these materials on other programs, our experience suggests that the opportunity of engineers, scientists and Navy personnel to experience the nature of sonar signals first-hand has greatly influenced their thinking on desirable display and signal processing techniques and their concept of operational problems.

During the current contract HFR has supplied recorded target signals to the following agencies: Stanford Electronics Laboratories; Bell Helicopter; Litton Industries; General Dynamics/Electronics; Melpar Incorporated; and Northrup-Ventura. It has also supplied selected materials to the U.S. Naval Training Device Center, the Royal Canadian Navy, and the U.S. Navy Training Aids Facility for use in the development of shipboard training kits.

Presentations and Information Exchange.

The Project Director has had frequent opportunities to make presentations of the work performed under this contract to both Navy and industrial personnel. These have included:

Admiral Karabaris
Admiral Reich (COMASWGRP V)
Admiral Harty (COMASWGRP III)
First Fleet ASW Board
ASWFORPAC Staff
Scripps Institute of Oceanography
TRW Incorporated

*AQS-10 data collection was supplemented by funds from the Bureau of Naval Personnel; recorded target signals for the BQQ-2 test were furnished through the Bureau of Naval Personnel.

Dunlap and Associates
Northrup-Ventura
Raytheon

The Project Director also has had the privilege of participating in two TRIPARTITE seminars, one on sonar target classification and another on ASW training equipment and systems design. In addition, liaison has been established with a number of laboratories and training centers throughout western Europe. The exchange of information and ideas on human performance problems and design considerations is ASW systems, as well as training of operators and maintenance technicians, has been most valuable. Liaison has been established and maintained with:

Admiralty Research Laboratory, Applied Psychology Unit
Admiralty Underwater Weapons Establishment
Norwegian Naval Training Establishment
Swedish Military Psychological Institute
CERPA (France)
Laboratorie de Detection Sous-Marine (France)
Institute for Perception RVO-TNO (The Netherlands)
Sonar Training Center (The Netherlands)
Sonar Training Center (Denmark)
Joint ASW Training Center (Londonderry)
SACLANT ASW Research Center, La Spezia

Project Personnel

The following members of the HFR professional staff have worked on one or more projects completed during the course of this contract:

C. H. Baker	R. J. Hall	J. J. McGrath
D. N. Buckner	A. Harabedian	J. F. O'Hanlon
D. A. Davidson	W. R. Harper	E. L. Parker
J. F. DePauli	J. F. Hatcher	J. C. Rittger
W. D. Dods	D. H. Harris	M. L. Seltzer
W. F. Dossett	W. S. High	H. K. Simpson
R. A. Gavin	R. R. Mackie	B. J. Tabachnick